KFKI

5/1969

PULSED NEUTRON GENERATOR FOR REACTOR PHYSICS (NIG-200)

Z. Szabó and I. Dékány

HUNGARIAN ACADEMY OF SCIENCES
CENTRAL RESEARCH INSTITUTE FOR PHYSICS

BUDAPEST

PULSED NEUTRON GENERATOR FOR REACTOR PHYSICS /NIG-200/

Z. Szabó and I. Dékány
Central Research Institute for Physics, Budapest, Hungary

Abstract

A pulsed D-T neutron generator developed and built for measurements in multiplying media is described. The pulse target current is 5 mA, the neutron yield during the pulse $\sim 10^{11}$ n/s. The pulse length is variable from 10 μs to 1 ms, the repetition frequency from 0,1 to 2000 pps, the maximum duty cycle is 2 %. The accelerating tube can be set to any position between the horizontal and vertical directions. The height of the rotational axis of the accelerating tube is variable from 0,90 m to 2,00 m above floor level. The 180 kV accelerating voltage is supplied by an insulating core transformer.

Investigations in the Reactor Laboratory of the Central Research Institute for Physics necessitated the development of a pulsed neutron generator for measurements in multiplying media. High neutron yield, wide range of neutron pulse lenghts and versatility of the equipment had to be achieved.

Fig.1 shows a sketch of the neutron generator. Neutrons are produced by the D-T reaction: the Zr-T target <u>1</u> is bombarded with deuterons accelerated to 200 keV in accelerating tube <u>2</u>. Deuterons are produced in the rf ion source <u>3</u>. Accelerating voltage is supplied by insulating core transformer <u>4</u>. High voltage terminal <u>5</u> contains the prefocusing voltage source and the power supplies for the ion source. Insulation transformer <u>6</u> supplies mains voltage for the high voltage terminal. The transformer, in its turn, is fed from mains stabilizer <u>7</u>. Vacuum in accelerating tube <u>2</u> is produced by vacuum system <u>8</u>. The generator is controlled from console <u>9</u>.

A sectional view of the ion source and extraction system is shown in Fig. 2. The Rasotherm ion source 1 is fed with deuterium gas through bore 2.

A palladium leak combined with a hydrolyzer [1] supplies deuterium gas. Gas pressure in the ion source can be adjusted by varying the heating current of the palladium leak. Gas in the ion source is ionized by coil 3 and electromagnet 4. The extraction system has seven holes, it consists of plasma electrode 5 /molybdenum/ and extraction electrode 6 /stainless steel/. The dimensions of the extraction system were determined as described in [2]. The multihole extraction system was chosen because of lower gas consumption and more uniform current distribution on target. Molybdenum plate 5 is bordered into disc 7 isolated from base plate 8 by ceramic ring 9. 7 and 8 are joined by Araldite seal 10. Base plate 8 is at the potential of the high voltage electrode, while disc 7 is at the extraction potential.

Fig. 3 shows a block diagram of the electrical circuits feeding the ion source. The push-pull circuit of the oscillator has two transmitter tubes of type 3S035 T. Its operational frequency is 25 Mc/s, its power is approximately 1 kW. The operation of the pulsed oscillator is controlled by 300 V gate pulses fed to its grid. The oscillator is blocked between the pulses. The light pulses determining the start and the end of the oscillator pulse are fed through light pipes 6 from drive circuit 5 /on ground potential/ to the output stage 7 /on high voltage/. Light pulses are produced by glow lamps DGL 11-02 VO, and detected by transistors OC 615 [3]. Oscillator pulse lengths range from 10 μs to 1 ms, repetition frequencies from 0,1 to 2000 pps.

The power supplies of the ion source are in the high voltage terminal. Their output voltage can be varied by variacs 1, which can be adjusted either manually by front panel controls or by remote control with the use of servo-motors 3 and plexiglas shafts 2. The variac positions are currently displayed on the control console by means of synchros 4.

The 220 V mains voltage is supplied to the high voltage terminal from the transformer the secondary coil of which is insulated to 200 kV D.C.

Fig. 4 shows a sketch of the high voltage terminal. Its units are mounted in racks and it is connected to the ion source block by cables in a corrugated metal tube. The high voltage terminal is provided with an earthing rod operating automatically when the accelerating voltage is switched off or the accelerating room door is opened.

Ions are accelerated and focused on the target in the accelerating tube /Fig. 5/. The focusing system is formed by two lenses; prefocusing lens /electrodes 1 and 2/ and accelerating lens /electrodes 2 and 3/. Electrode 1 is at high voltage terminal potential, electrode 3 is earthed, and the potential of electrode 2 is variable with respect to that of electrode 1 in the range from 0 to -30 kV to adjust focal distances of the lens. Cylinder 4 prevents the charging of porcelain insulator 5 in the vicinity of the lenses. Gate valve 10 serves to avoid air admission into the vacuum system when changing target 13. Quadrant 12 indicates the ion beam position, the target can be centered by device 11.

The accelerating tube is evaquated by a 1500 l/s oil diffusion pump and a 25 m^3/h roughing pump /Fig. 6/. A liquid nitrogen cold trap is provided to minimize target contamination by oil vapours. The cold trap and the diffusion pump can be isolated from the accelerating tube by a semi-automatic disc gate valve which is opened manually and closes automatically in case of mains failure. Magnetic valves permit to connect the roughing pump either to the diffusion pump or directly to the accelerating tube.

The vacuum pumps join the vacuum manifold via a tube of 1 m lenght. The accelerating tube can be tilted to 90° continuously without breaking the vacuum. The accelerating tube position can be changed in steps of 30° on breaking the vacuum providing thus 12 possible starting points.

Details of the 90° tilting mechanism of the accelerating tube are shown in Fig 8. Tube 1 under vacuum can be turned by 90°. Tube 2 is fixed and supports tube 1 by means of rollers 4. Nut 9 slides on screw shaft 7 rotated by handwheel 8, and shifts by means of pin 6 the clamp 5 fixed on tube 1.

The lifting mechanism of the vacuum pump block is sketched in Fig. 9. Screw shafts 2 are driven by motor 1 via reducer and bevel gear. The screw shafts, suspended inside vertically slit tubes 4, lift the vacuum pump block by means of sliding nuts 3. The unit is led by rollers along tubes 4 and 5.

The accelerating voltage is supplied by a 200 kV insulating core transformer [4].

Figs 10. and 11 show the neutron generator and the control console.

During the test of the vacuum system, the pressure was measured at two points; directly above the cold-trap /p_1/ and at the ion source end of the accelerating tube $/p_2/$. The deuterium gas leaving the ion source in operation caused an increase in pressure due to the flow resistance of the accelerating tube and the connecting tubes. $p_1 = 3{,}8.10^{-5}$ Hg mm and $p_2 = 6.10^{-5}$ Hg mm were measured. After pumping for several days the pressure was measured as $p_1 = 5.10^{-6}$ Hg mm with the ion source in operation and the cold trap filled with liquid nitrogen.

Initially the 200 kV power supply was connected to the high voltage terminal. However, the small high voltage discharges - always present in accelerating tubes, especially at the initial stage - often caused the fuse of the oscillator power supply to blow out. This can be explained by high voltage transients due to the inductance of the cables connecting the ion source block and the high voltage electrode. The 200 kV power supply was therefore connected directly to the ion source block eliminating thereby the above inconvenience.

High voltage breakdown between the plasma and the extraction electrode was a serious problem until the extraction electrode /Fig. 2., 6/, originally made of aluminium [2], was changed to stainless steal.

A current of 15 mA can be reproducibly extracted from the ion source. The spot diameter at the target is 20-22 mm as calculated. At present targets of 14 mm diameter are used, the current of 5 mA measured on their surface has been sufficient for the measurements so far, but - when necessary - targets of larger diameter can be used to exploit the entire current of the beam.

Fig 12. shows target current pulses of different lengths taken with EMG 1546 oscilloscope, form a 1 kohm resistor /1 V $\div$ 1 mA/. Secondary electrons were suppressed. The horizontal and vertical scales of the oscilloscope, the extraction and oscillator anode voltages are given in the figure.

After the test run of the neutron generator in April 1968, it was installed beside the zero power reactor ZR-4. Since then, it has been operated for measurements on reactor transients and pulsed reactivity [5], [6].

References

[1] Z. Madarász; Z. Szabó: KFKI Közl. 11, /5/ 421-423 /1965/

[2] A.N. Serbinov, V.I. Moroka: PTE /5/ 27-31 /1960/

[3] L. Garamszegi: to be published

[4] Z. Szabó: KFKI Közl. 15, /6/ 367-372 /1967/

[5] Z. Gyimesi; J. Valkó: 5 RC/25, 5th Conference on Physics and Technique of Research Reactors, Warsaw, December 16-21, 1968

[6] Z. Szatmári, L. Turi: 5 RC/31, 5th Conference on Physics and Technique of Research Reactors, Warsaw, December 16-21, 1968.

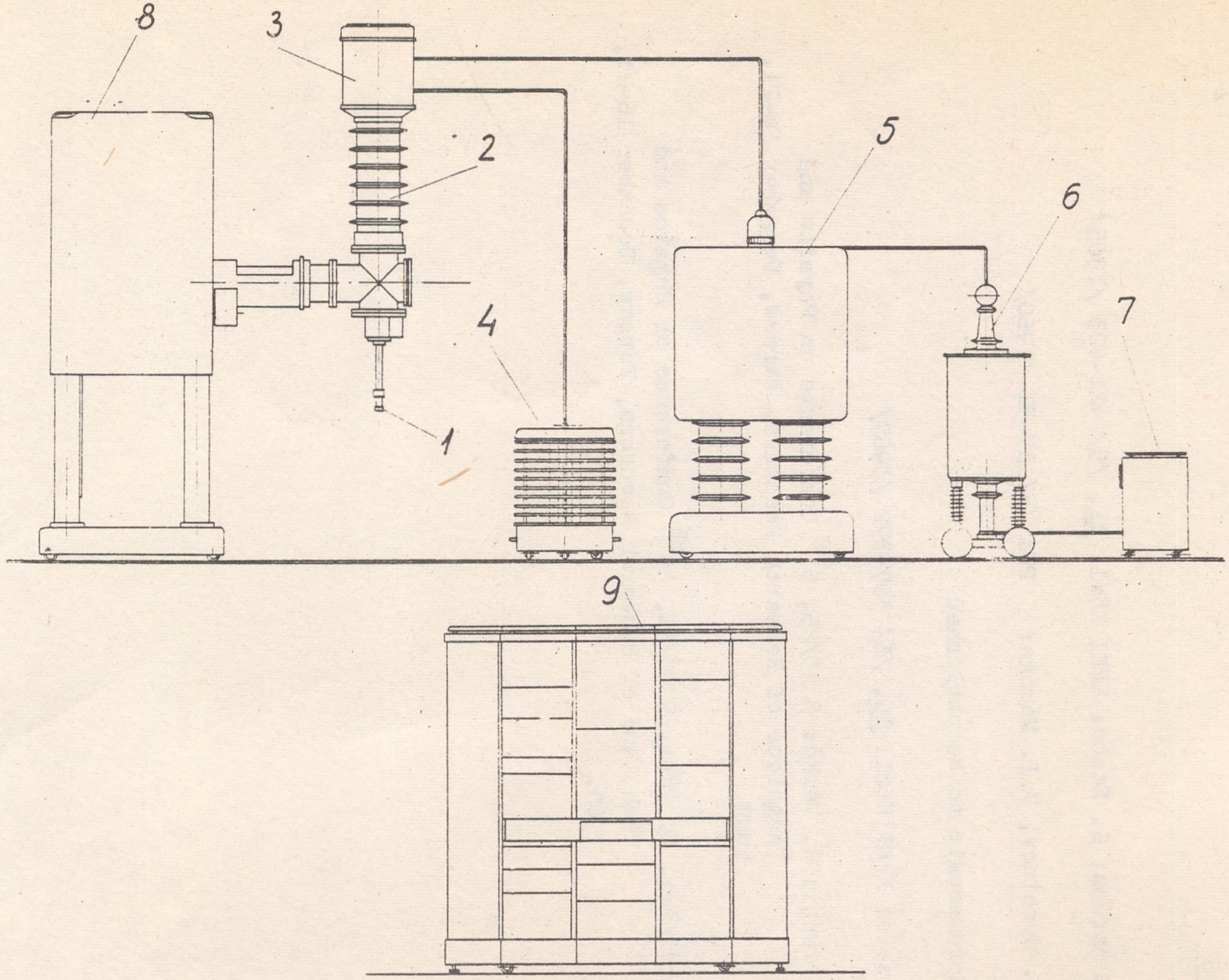
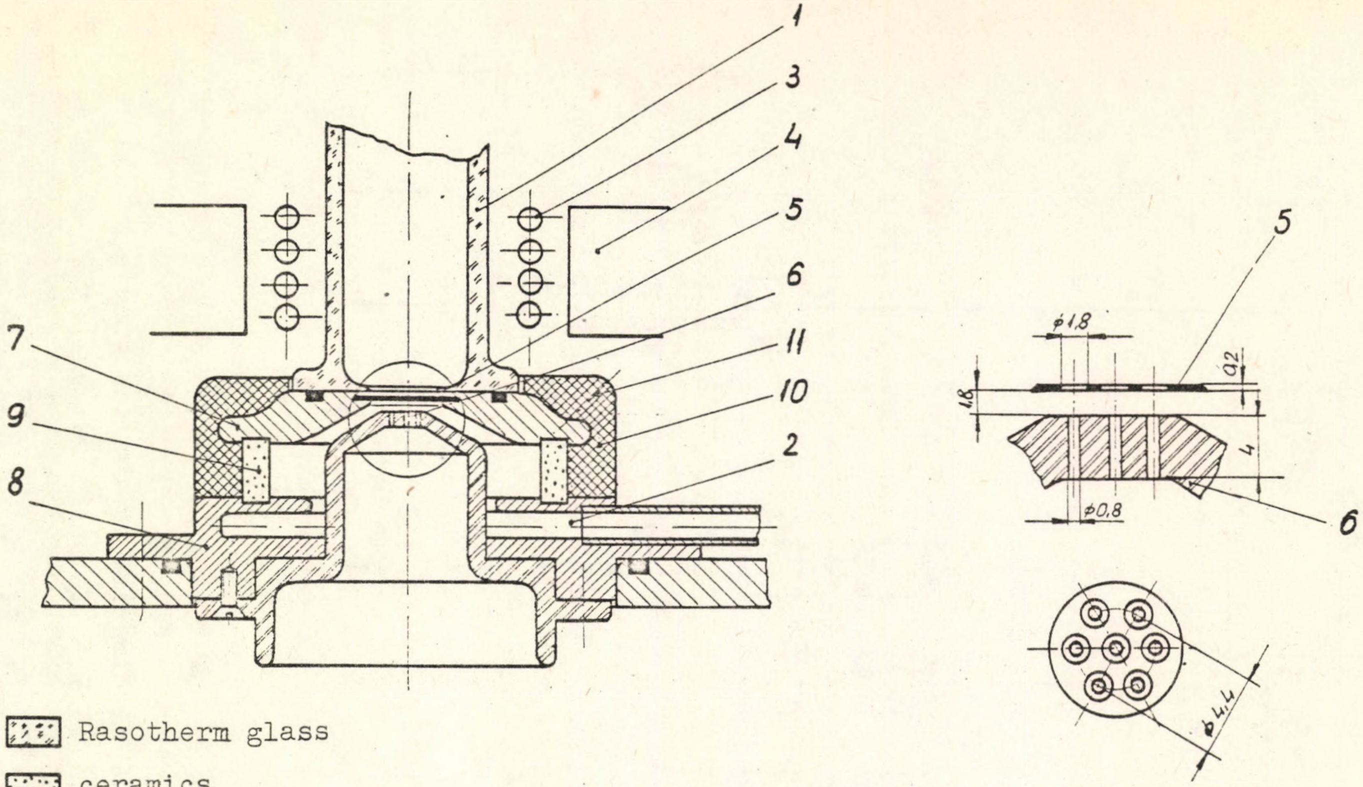


Fig. 1

Sketch of neutron generator

1 - target; 2 - accelerating tube; 3 - ion source block; 4 - 200 kV power supply;
5 - high voltage terminal; 6 - insulating transformer; 7 - mains supply stabilizer;
8 - vacuum pump block; 9 - control console



Rasotherm glass

ceramics

Araldite seal

steel

stainless steel

aluminium

rubber

Fig. 2

Ion source and extraction system

1 - ion source; 2 - gas inlet; 3 - oscillator coil; 4 - electromagnet; 5 - molybdenum plasma electrode; 6 - extraction electrode; 7 - disc; 8 - base plate; 9 - distance ring; 10 - Araldite seal; 11 - extraction voltage feed through

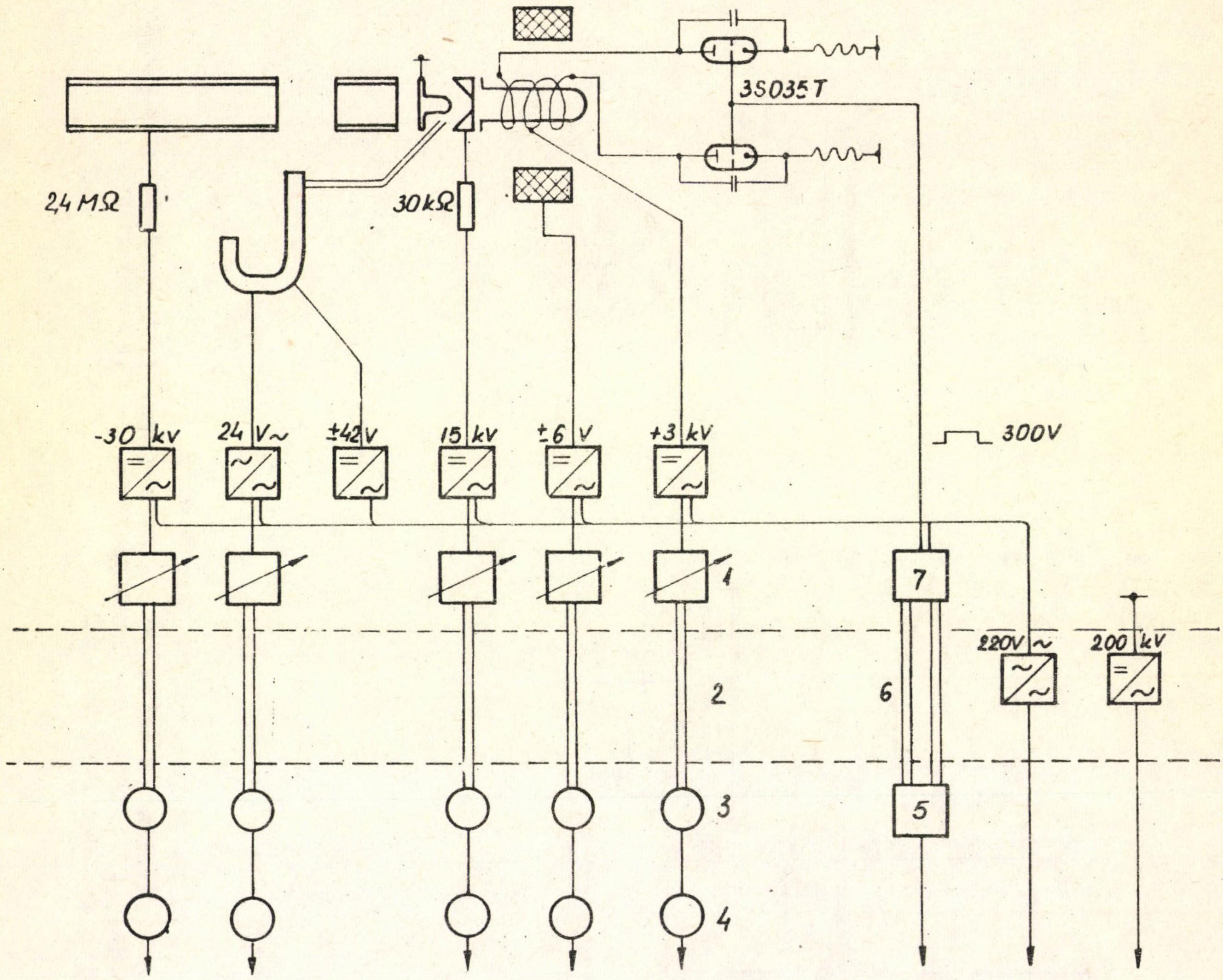


Fig. 3

Electrical circuits of the ion source

-30 kV prefocusing voltage; 24 V ~ filament voltage of Pd leak; ± 42 V hydrolyzing voltage; + 15 kV extraction voltage; ± 6 V electromagnet: + 3 kV oscillator power supply: + 300 V gate pulse for oscillator; 220 V mains supply for high voltage terminal: 200 kV accelerating voltage.

1 - variac; 2 - plexiglas shaft; 3 - servo motor; 4 - transmission synchro; 5 - pulse generator drive circuit; 6 - plexiglas lightpipes; 7 - pulse generator output stage

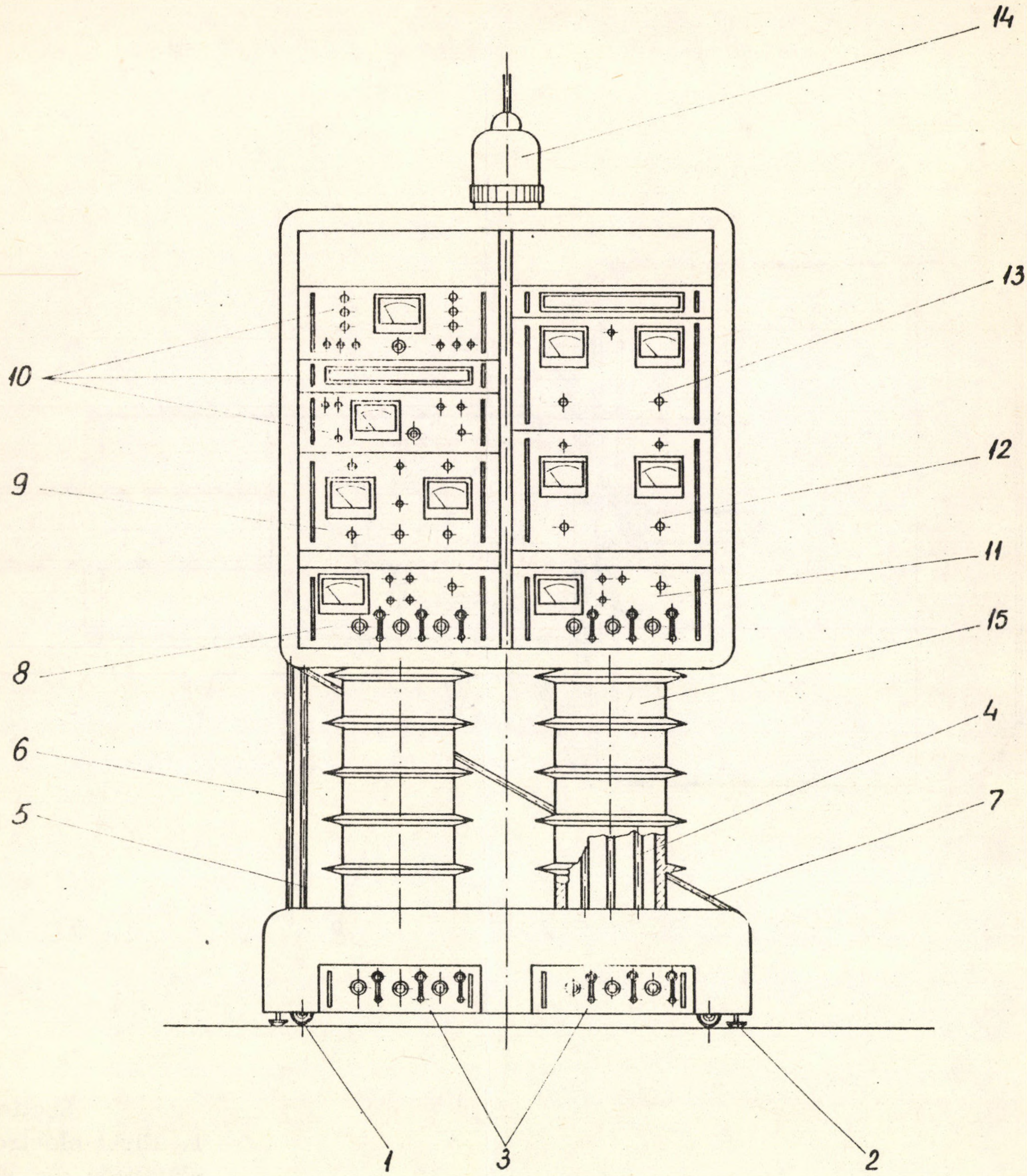


Fig. 4.

High voltage terminal

1 - castor; 2 - positioning jack; 3 - servo motors and synchros; 4 - plexiglas shaft; 5 - plexiglas lightpipe; 6 - automatic earthing rod; 7 - series resistor for 200 kV; 8 - power supply for electromagnet; variacs; 9 - oscillator power supply; 10 - pulse generator output stage; power supply; ventillator; 11 - hydrolyzer power supply; variacs; 12 - prefocusing voltage source; 13 - extracting voltage source; 14 - cable connection to ion source block; 15 - porcelain insulator.

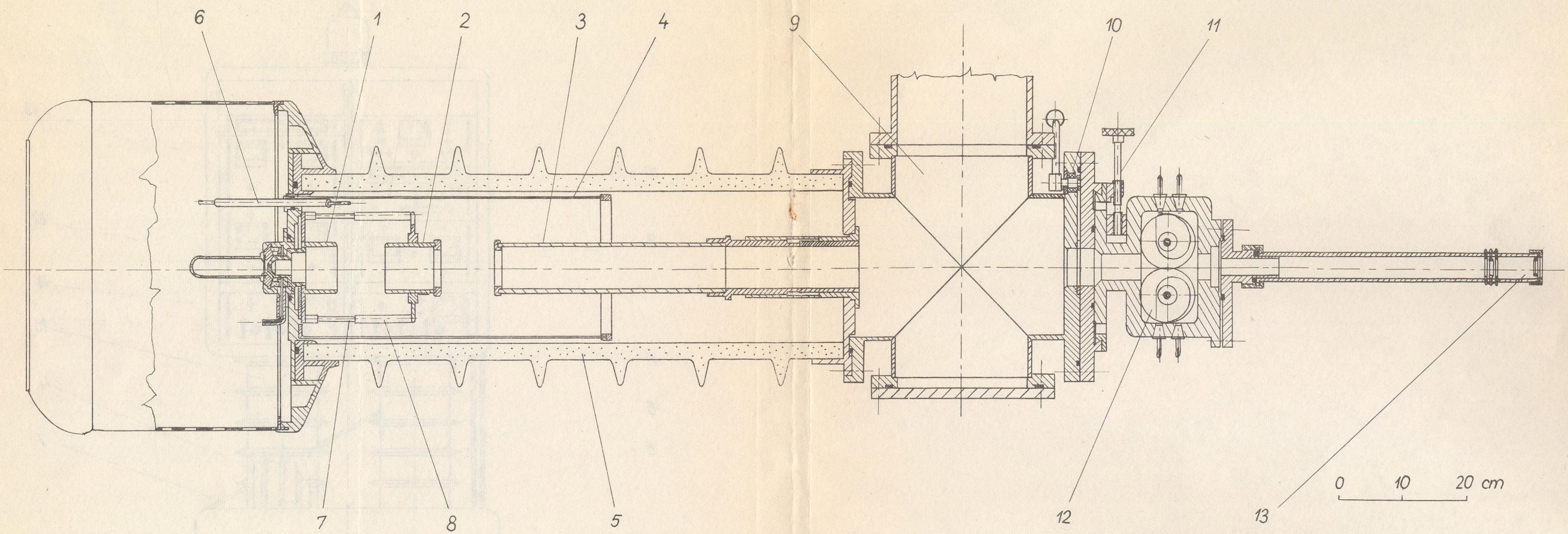


Fig. 5.

Sectional view of the accelerating tube

1. First electrode, 2. intermediate electrode, 3. earthed electrode, 4. shielding cylinder, 5. porcelain insulator, 6. prefocusing voltage feedthrough, 7. ceramic rod, 8. metallic rod, 9. vacuum manifold, 10. gate valve, 11. target centering device, 12. quadrant, 13. target

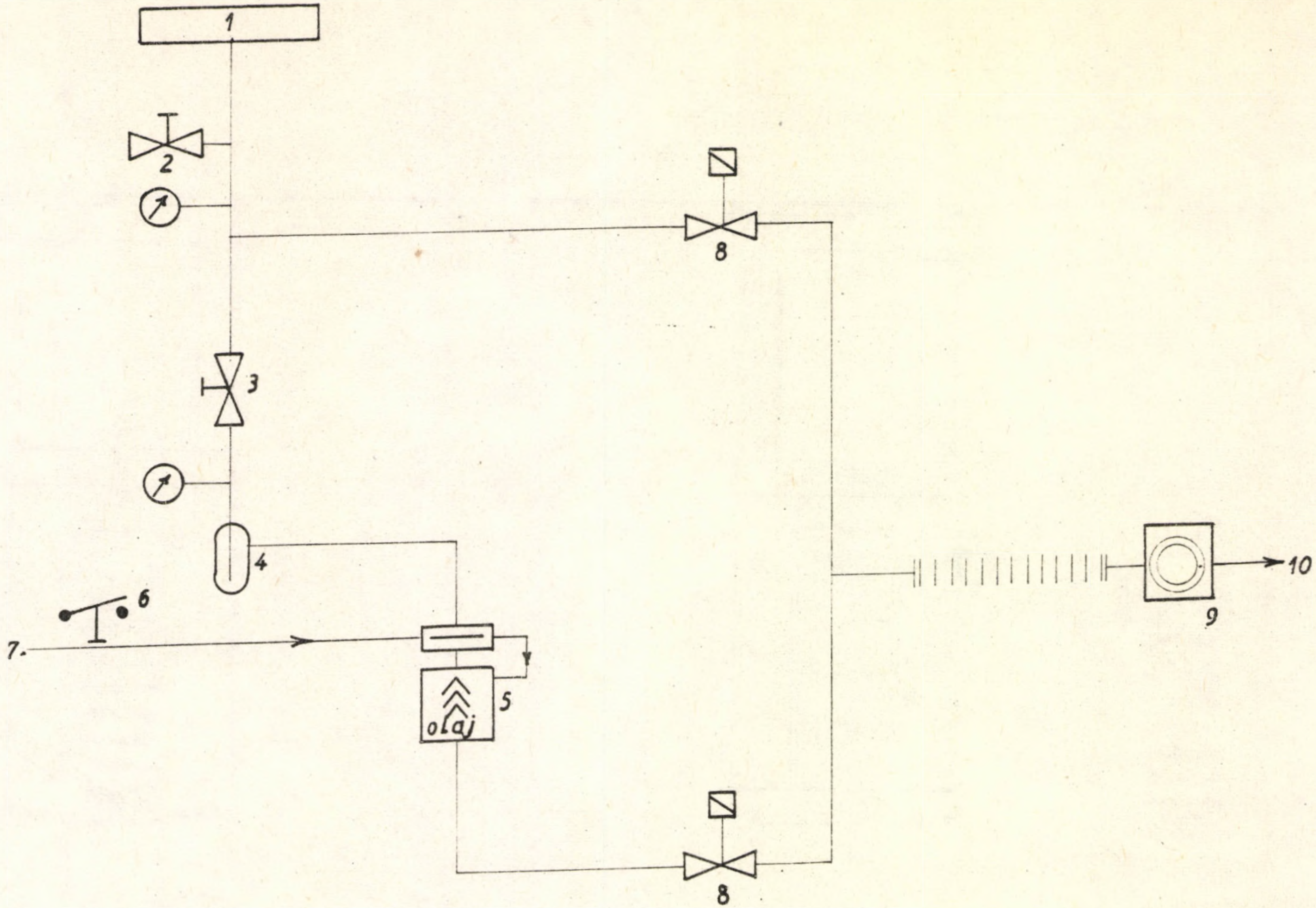


Fig. 6

Scheme of vacuum system

1 - accelerating tube; 2 - air inlet valve; 3 - disc gate valve; 4 - cold trap; 5 - oil diffusion pump; 6 - safety switch for water stoppage; 7 - cooling water inlet; 8 - magnetic valve; 9 - roughing pump; 10 - exhaustion

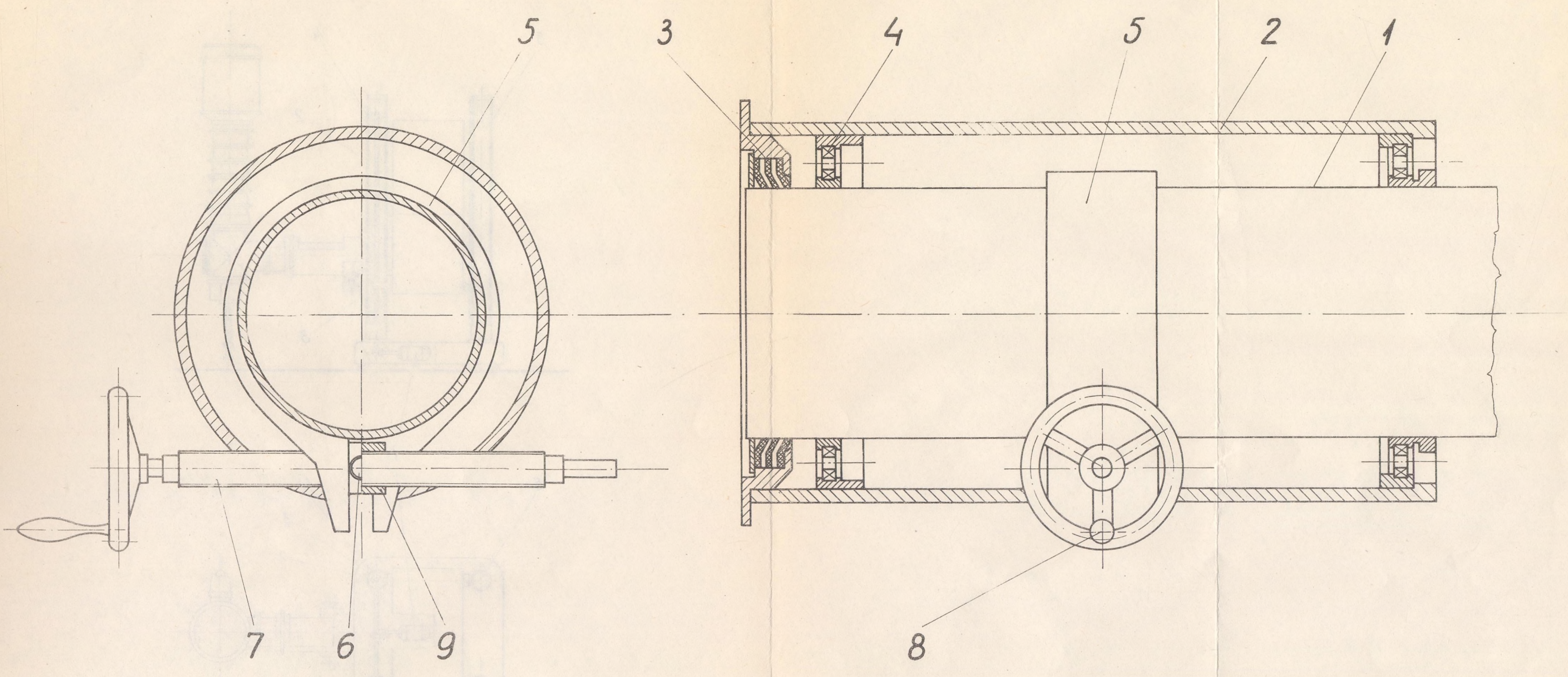


Fig. 8.

Accelerating tube tilting mechanism

1. rotating tube kept at vacuum, 2. supporting tube, 3. Wilson joint, 4. roller, 5. clamp, 6. pin, 7. screw shaft, 8. adjusting handwheel, 9. sliding nut

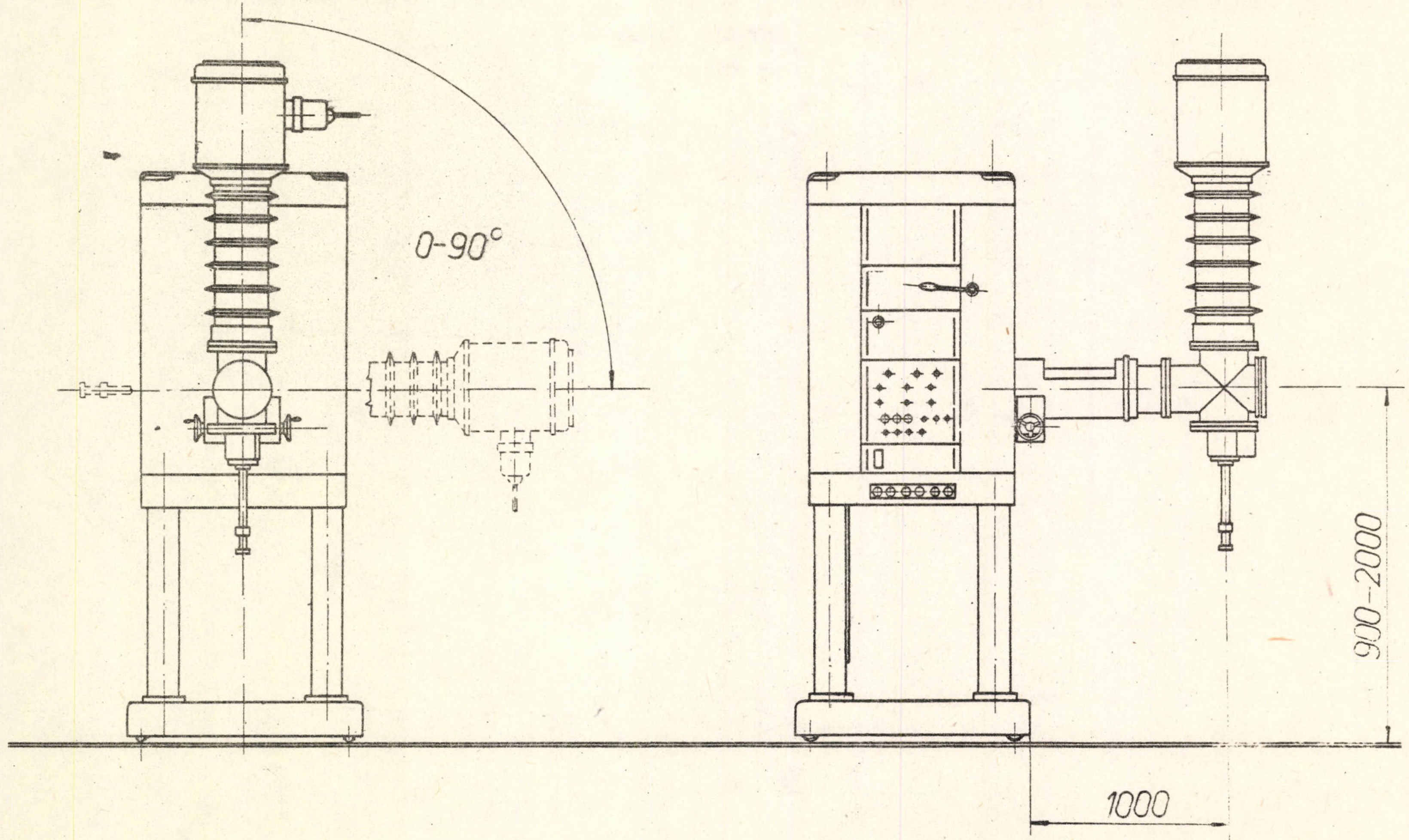


Fig. 7
Possible positions of accelerating tube

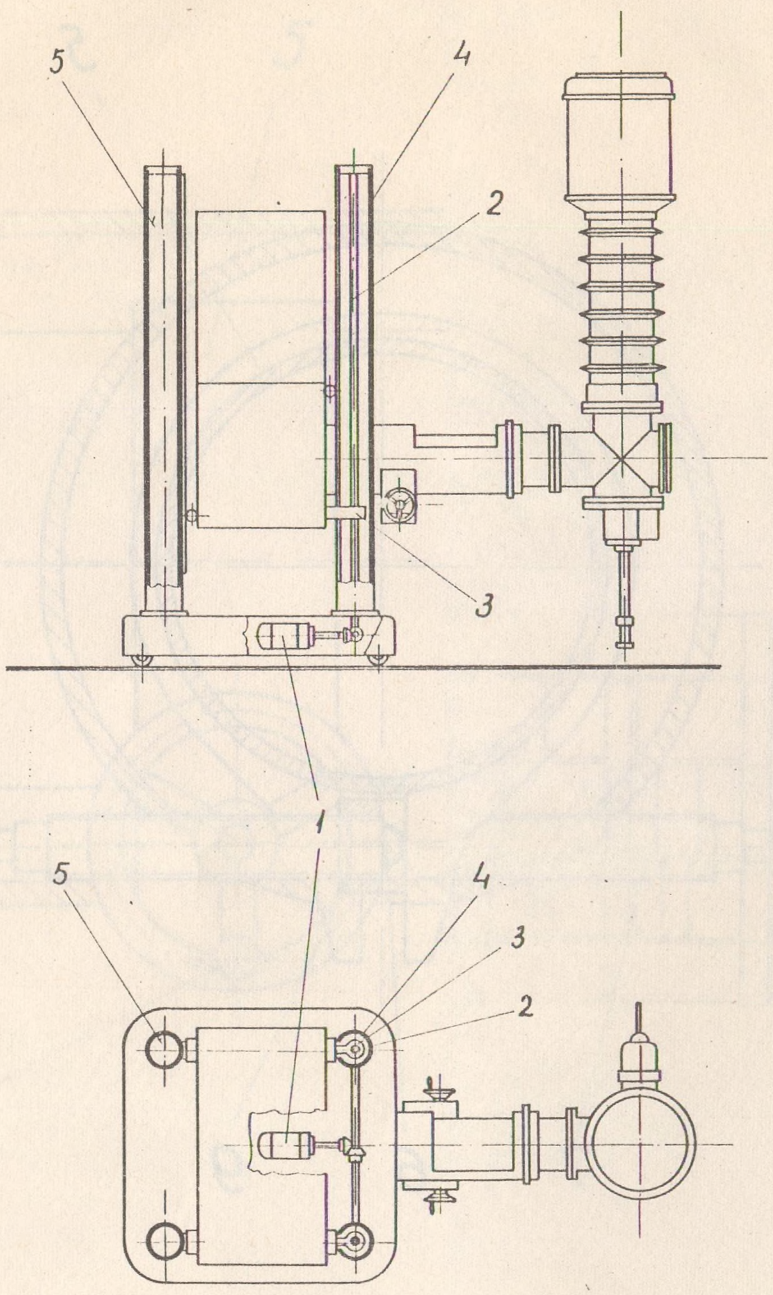


Fig. 9
Accelerating tube lifting mechanism
1 - motor; 2 - screw shaft; 3 - sliding nut; 4 and 5 - supporting tubes

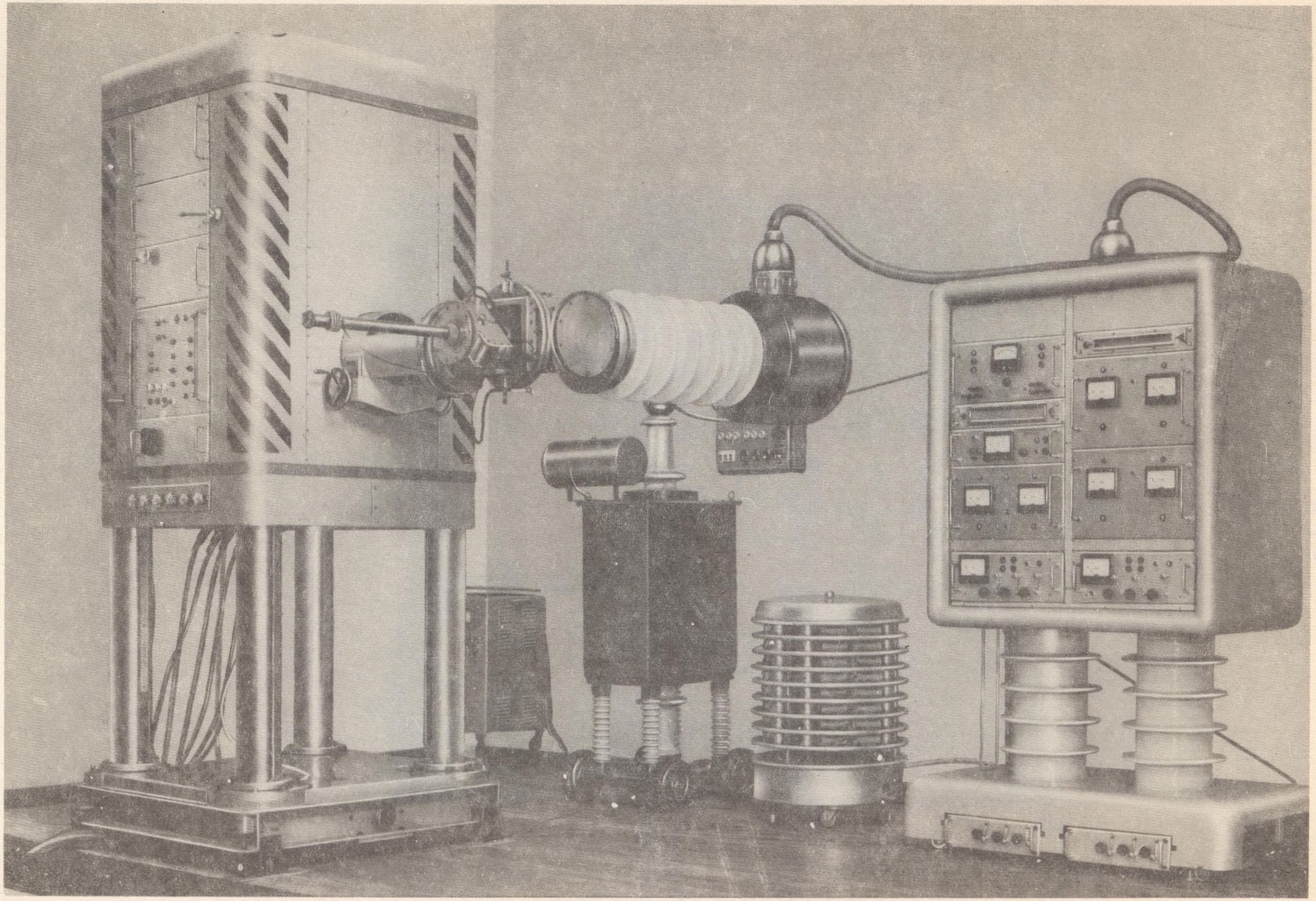


Fig. 10
Neutron generator NIG-200

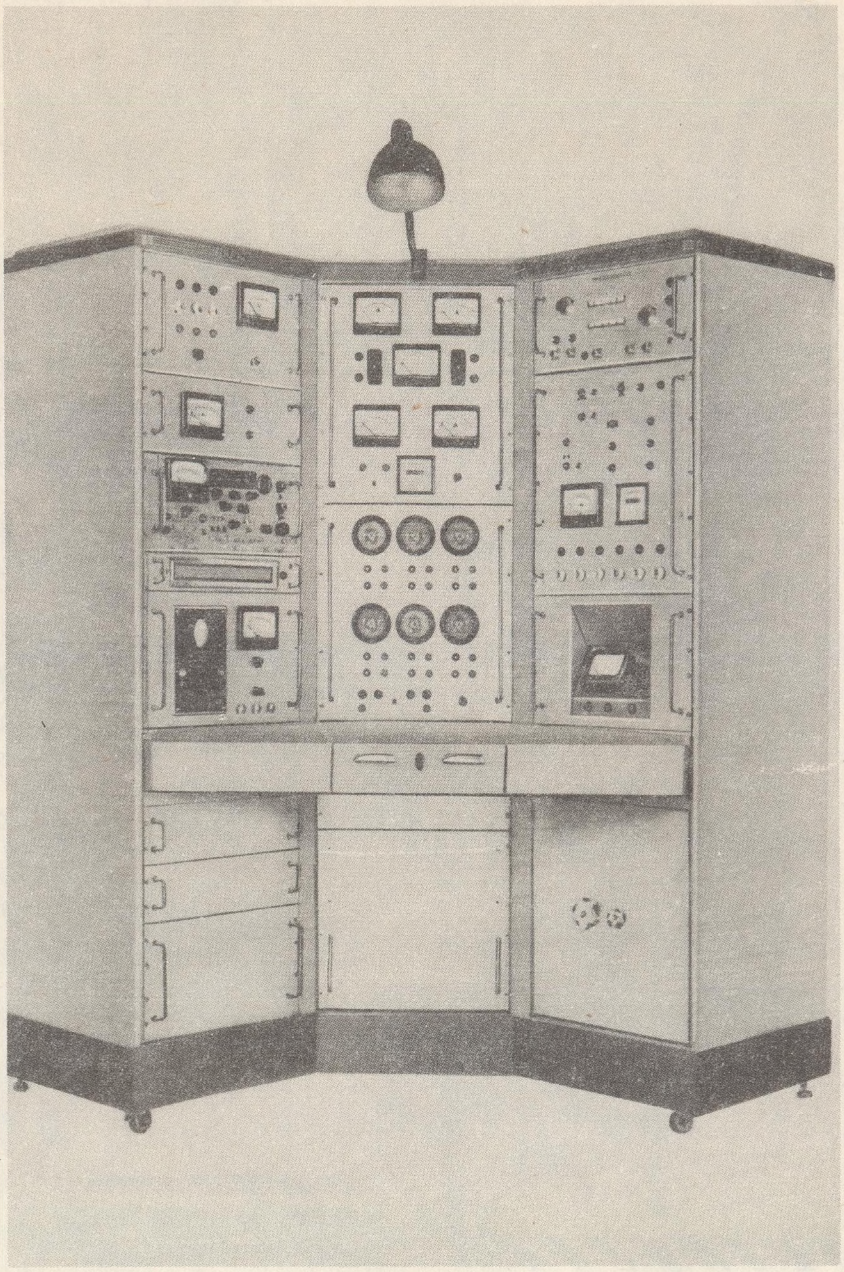


Fig. 11
Control console

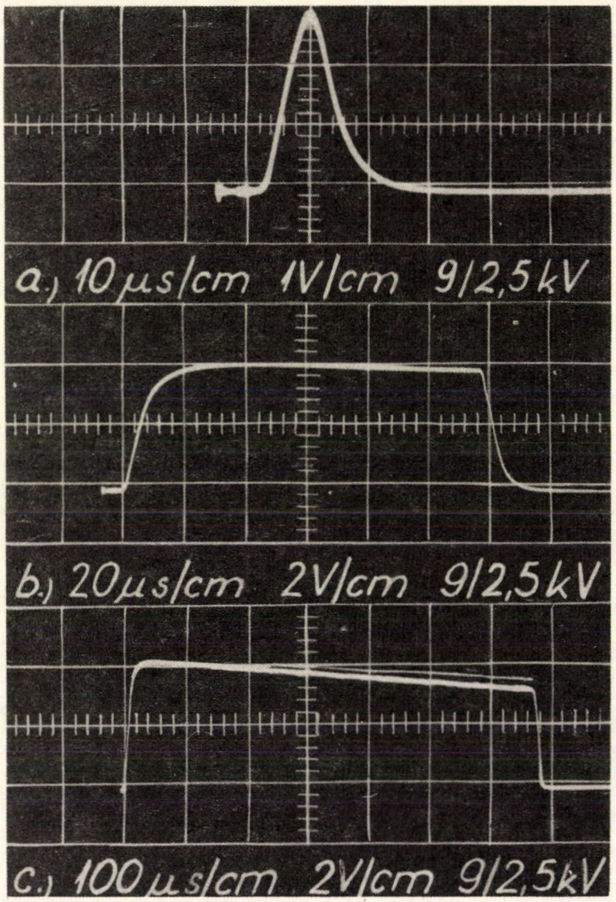


Fig. 12
Target current pulses

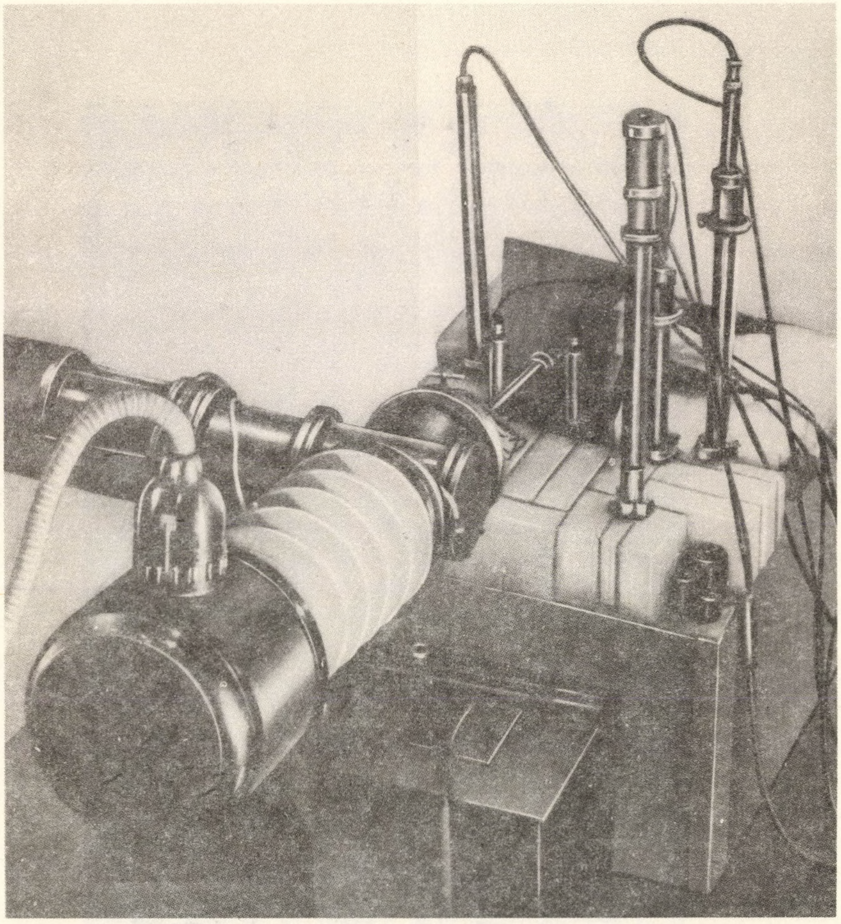


Fig. 13
Experimental arrangement at zero power reactor ZR-4

Printed in the Central Research Institute for Physics, Budapest
Kiadja a MTA KFKI Könyvtár és Kiadói Osztály. ov.: dr. Farkas Istvánné
Példányszám: 125 Munkaszám: 4188 Budapest, 1969. január 16.
Szakmai lektor: Pásztor Endre. Nyelvi lektor: Kovács Jenőné
Készült a KFKI házi sokszorositójában. Fv.: Gyenes Imre